STUDIES OF ROOT DISTRIBUTION AND ROOT ANATOMY OF *PASPALUM DISTICHUM* L.

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Abstract

Paspalum distichum *L. is a perennial grass species which grows in water ditches or in badly water-logged soils along water courses in the West Pakistan plains. The root system of this species has been described. Reported here are the results obtained from the studies of* (i) *the distribution of the roots in the soil in the field, and* (ii) *the amount of intercellular spaces present in the cortex of the roots as they are growing at different depths in the soil.* P. distichum *should be regarded if not a shallow-rooting species, at least one which is intermediate between shallow-rooting and deep-rooting species. The intercellular spaces in the cortex of the old cord root have been found to increase with an increase in soil depth. The presence of these spaces should be considered as an adaptation for growth in poorly aerated media.*

Introduction

Paspalum distichum L. is a perennial grass species found growing in water ditches and in badly water-logged soils along water courses (canals, etc.) in the West Pakistan plains. This species along with other amphibious ones—*Scirpus maritimus*, *Polygonum barbatum*, *Cynodon dactylon*, etc.—forms a stage in the succession of vegetation starting from water ditches which may ultimately reach a climax in *Typha angustata* and *Phragmites karka* type of community before these ditches get filled up (Chaudhri 1960).

Previous researches have shown that the plants which grow in water-logged soils can do so because of their ability to take oxygen from the air above the soil through their leaves and transfer it, by internal diffusion, down to the roots which have to experience a deficiency of oxygen in these soils (Conway 1937, Van Raalte 1940, 1943, Coult and Vallance 1958, Barber *et al.* 1962, and Teal and Kanwisher 1966). The development of a large amount of intercellular spaces in the cortex of the root may facilitate this internal diffusion of gases (Barber *et al.* 1962, Sheikh 1966).

The studies of the root system of a species form a very important part of the investigations concerning its ability to grow in water-logged soils. Keeping this in view, some root studies have been carried out on *P. distichum*. These studies include the investigations of (*i*) the distribution of the roots in the soil, and (*ii*) the amount of intercellular spaces present in the cortex of the roots (cortical spaces) as the latter are growing at different depths in the soil.

Methods

P. distichum was the only species growing in a depression (approx. 30 sq. ft. area) in the *Cynodon dactylon* type of community (Rutter and Sheikh 1962) on the northern side of Muhammad Ali Jauhar Hall at the New Campus of the University of the Panjab, Lahore. About half inch of water was standing at the soil surface. The root studies reported here were carried out on samples obtained from this site.

Root distribution

In order to study the general appearance of the root system a small patch of *P. distichum* was removed with the help of a spade and the roots were washed free from soil by using a fine jet of water.

A 'nail-board' was used for sampling the roots in order to study their distribution at different depths in the soil. The 'nail-board' was a rectangular board of wood, 12 in. wide and 18 in. long, through which 3 in. long nails projected on one side at right angles to the major plane of the board. There were five rows of nails along the length of the board and each row of nails was 3 in. apart from the next one. Along the width of the board there were three nails in each row. This arrangement divided the board, along its length, into six horizons—each 3 in. deep, 12 in. wide and 3 in. high (108 cu. in. vol.).

In November, 1967 two sampling spots were selected at random at the site of study. At a sampling spot, a small trench was dug and the 'nail-board' was inserted into its side so that the nails penetrated into the soil. The soil around the board was then cut with a bread-knife so that a soil monolith remained on the board held by the nails. A rectangular wooden board of the same size as the 'nail-board' was secured to the latter at the four corners, above the soil monolith, using long nuts and bolts. This checked the loss of soil from the 'nail-board' during transportation to the laboratory. As mentioned earlier, two such soil monoliths were sampled at random from the site understudy. Description of the soil profile was made from these samples. pH determination of the soil was made on a soil: water suspension (1:2) with a Cambridge pH meter.

Using a bread-knife, the soil monolith was cut into horizons along the nails. Soil horizon was washed with a jet of water. The water used in this washing drained away through a fine-meshed sieve (60 B.S.S.) which retained the roots. Using this method of washing even very fine roots were not lost. The roots thus obtained in the different soil horizons were dried in the oven at 80 C for 24 hrs and were weighed on a Mettler balance. In the first horizon (0–3 in.) the roots were carefully separated from the creeping root-stock. No attempt was made to separate the living roots from dead ones, and the root weights reported here include living roots and dead ones which were not sufficiently decomposed to be unrecognisable.

Root anatomy

Old cord root

An old main root(= cord root, see below) was carefully dissected out from the soil to its maximum depth of penetration which in this case was 15 in. It did not have a growing tip. For each soil horizon one piece of 1 in. length was cut from the root except the first horizon (0–3 in.) where two such pieces were obtained (1–0 in. and 2–3 in.). Transverse sections of these root pieces were cut with a microtome and were double stained using Safranin—Fast green combination. From the transverse sections obtained from a root piece, one was selected at random and a camera lucida drawing of it was used for measuring the areas of the root and the cortical spaces. A planimeter was used for making these measurements.

New cord root

A new cord root was dissected out from the soil. It was 12 in. in length and had a growing tip. As in the case of the old cord root, pieces of 1 in. length were cut from it and using the procedure outlined above the measurements of the areas of the root and the cortical spaces were taken.

Results

Root system

Root system of *P. distichum* can be described as being composed of main roots which are cylindrical in appearance and their fine branches. The main roots can be called cord roots and their branches fibrous roots. The new cord roots are light creamish whereas the old ones are darker in colour. The cord roots are copiously covered with primary branches that are branched further. These branches are called fibrous roots. The primary branches are well developed in the proximal part of the cord root, whereas in its distal part they remain thin and are seldom branched.

The cord roots have a great tensile strength. They arise from the nodes of the creeping root-stock from the side which comes in contact with the soil or water surface.

Soil profile

A general description of the soil profile is given in Table 1. This description is based on the study of the two monoliths sampled from the field.

Table 1. *Description of the soil profile*

Depth, in.	Colour, structure and texture	pH
0-3	Dark greasy clay, bound by many roots	8.00
3-8	Dark greasy clay, fewer roots, gleyed, *i.e.*, a cut surface shows a mottle of alternating brown (ferric) and blue black (ferrous) patches—a sing of deficient aeration.	8.15
>8	Light coloured loam	8.35

Keeping in view the very small number of samples (only 2) the absolute dry weights of roots in these samples agreed reasonably well (12.02 gm in I and 10.88 gm in II) because not very different amounts of above-ground parts (shoots and root-stock) of the species were present on the samples (16.54 gm in I and 14.45 gm in II). The figures given in Table 2 for the dry weights of roots in different horizons are means of the two values obtained from these samples.

Table 2. *Mean dry weight of roots of* P. distichum *in different soil horizons*

*Horizons	Soil depth, in.	Dry wt. of roots, gm
I	0—3	7.91
II	3—6	2.38
III	6—9	0.64
IV	9—12	0.33
V	12—15	0.13
VI	15—18	0.06

* Each soil horizon is 108 cu. in.

Fig. 1 shows the dry weight of roots (given in Table 2) expressed as a percentage of the total dry weight of the root system. *P. distichum* had almost 70% of its root system in the first 3 in. of the soil and the amount decreased with increase in soil depth, and below 6 in. only about 10% of the total root system was present. Roots were present, though very few (< 1%), down to the maximum depth of sampling (18 in.).

The cortex of the roots present below 6 in. was loose but intact. Some of the roots below 6 in. had an orange brown deposit on their surface.

Root anatomy

A T.S. of the cord root (Fig. 2) shows that the cortex is divisible into three zones: an outer 2-3 layered zone of thin walled cells of various sizes whose innermost layer is thicker walled as compared to the outer layer/layers; a middle zone of 6-7 layers of irregular thin walled cells which decrease in size towards the interior of the root, and by their tearing and dissolution result in the formation of large air spaces (=cortical spaces) between them; and an inner zone of 1-2 layers of small thin-walled cells. The stele has a sclerenchymatous ground tissue which is responsible for the great tensile strength of the root.

FIG. 2

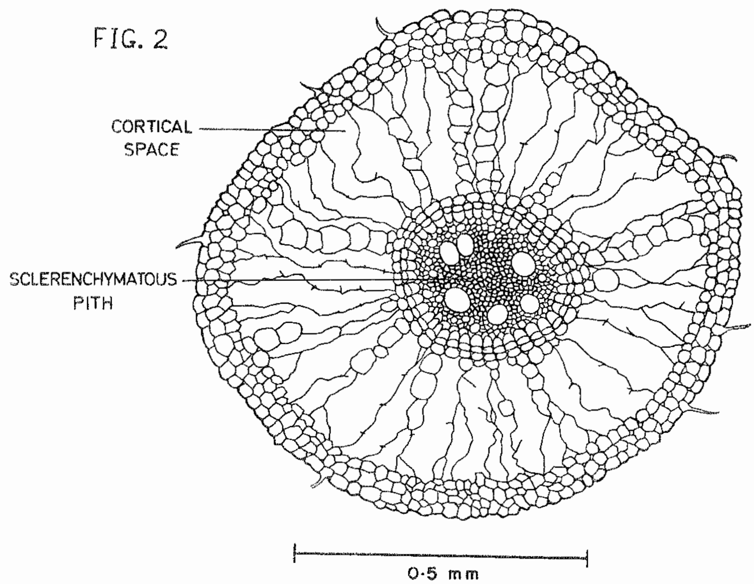

Fig. 2. *P. distichum*: Transverse section of an old cord root from 5-6 inches soil depth.

In Fig. 3 the amount of the cortical spaces has been expressed as a percentage of the total root area because of the different sizes of the roots obtained from different depths.

In the old cord root the amount of the cortical spaces, expressed as a percentage of the total root area, increased with increasing soil depth. The large increase in the percentage of the cortical spaces at lower soil depths (below 9 in.) is due to

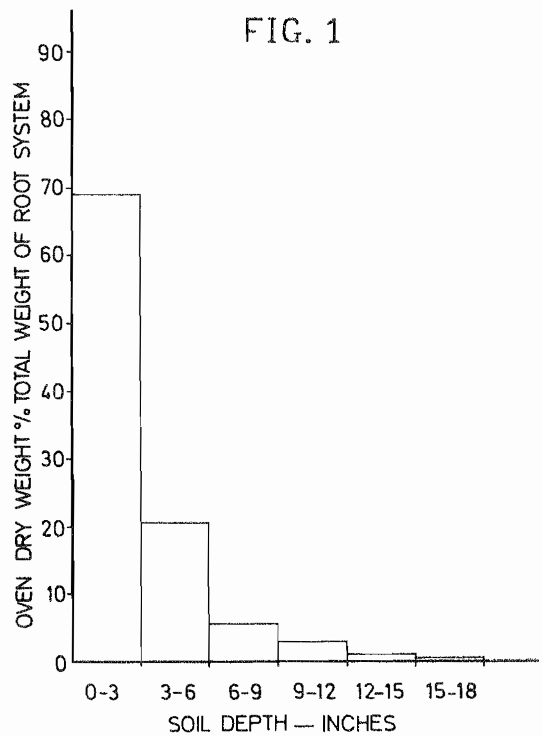

Fig. 1. *Paspalum distichum:* Dry weight of roots found at successive 3 inches soil depths, expressed as a percentage of the total dry weight of the root system.

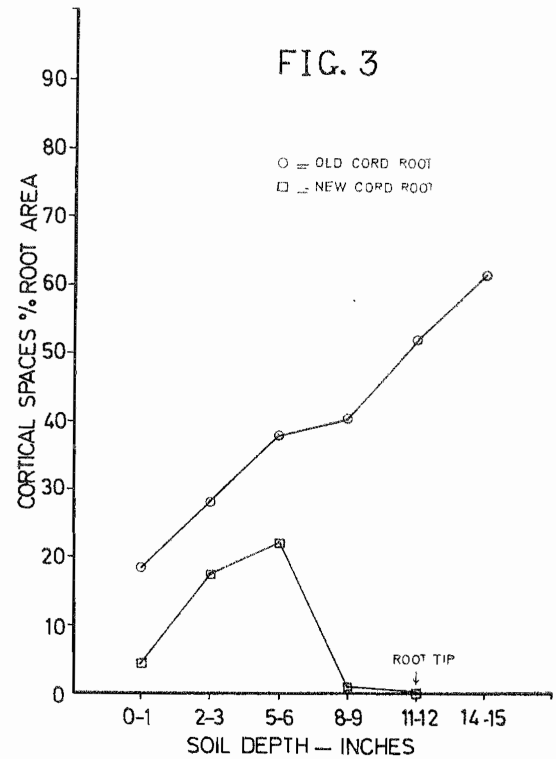

Fig. 3. Cortical spaces, % root area, in the old and new cord roots of *P. distichum.*

the decrease in the total root area rather than an actual increase in the former (Table 3).

Table 3. *Cortical spaces in the old cord root*

Soil depth (in.)	Area of root (sq. mm.)	Area of cortical spaces (sq. mm.)	Cortical spaces, % root area
0—1	86.8	16.2	18.7
2—3	85.5	24.2	28.3
5—6	78.7	30.1	38.2
8—9	70.7	28.5	40.3
11—12	54.3	28.3	52.1
14—15	45.5	27.9	61.3

In the new cord root the percentage of the cortical spaces increased up to a depth of 6 in. and below this, it decreased until near the root tip there were no spaces (Fig. 3).

The cortical spaces were also present in the fibrous roots but these were not measured.

Discussion

The 'nail-board' method of root sampling has been used fairly widely and the size of the board and the size and position of the nails have varied greatly between workers (Blaser 1937, Goedewaagen 1948, 1949, Salonen 1949, Schuster 1964 and Sheikh 1966).

In the present work the maximum depth of penetration of the roots of *P. distichum* has not been studied but their distribution at different soil depths suggests that though the roots may penetrate deeper than 18 in. in the soil, the amount of roots at such depths would be negligible.

P. distichum should be regarded if not a shallow-rooting (surface-rooting) species, at least one which is intermediate between shallow-rooting and deep-rooting species.

The cortical spaces in the roots of *P. distichum* are lysigenous in origin and the occasional remains of the cell walls can be seen projecting into these spaces (Fig.2). Intercellular spaces in the cortex of the roots of *Zea mays* (McPherson 1939), *Oryza sativa* (Katayama 1961) and *Molinia caerulea* (Sheikh 1966) have also been reported to be lysigenous in origin.

In the cord root there is an increase in the amount of cortical spaces with an increase in the distance from the root tip until a maximum is reached 5 – 6 in. below the soil surface. Katayama (1961) has found an increase in the amount of cortical spaces with an increase in the distance from the root tip in the roots of upland rice and corn. Sheikh (1966) has obtained similar results in the new cord roots of *Molinia caerulea.*

In the light of the work of Weaver and Zink (1945) on the process of the degeneration of the root cortex of the grasses, it can be safely stated that the old part of a root (*i.e.*, that near the soil surface), will be the first to lose its cortex. Therefore, if the increase in the cortical spaces is due to the decay process, the old part should have more cortical spaces than the portions of the root in the deeper horizons of the soil. In view of this the increase in the cortical spaces in the old cord roots of *P. distichum* from the deeper soil horizons should not be regarded a consequence of the decay process.

The development of a large amount of cortical spaces may be regarded as an adaptation for growth in poorly aerated media. Many workers have found that the amount of intercellular spaces in the root cortex increases as the plants grow in the presence of abundance of water or in badly aerated media (Bryant 1934, Goosens 1936, McPherson 1939, Lundkvist 1955, Katayama 1961, Kacperska-Palacz 1962, Sheikh 1966). This well developed intercellular space system may not only provide a path for the internal diffusion of oxygen from the aerial parts but also the oxygen requirements may have been reduced by reducing the amount of respiring tissue.

An intercellular space system in the roots for the internal diffusion of oxygen into them from the shoots has been found in many plants, *e.g.*, *Cladium mariscus* (Conway 1937), *Oryza sativa* (Van Raalte 1940, 1943, Barber *et al.* 1962), *Menyanthes trifoliata* (Coult and Vallance 1958), and *Spartina alterniflora* (Teal and Kanwisher 1966). Barber *et al.* (1962) have shown that in *Oryza sativa* the transport of oxygen from the shoots to the roots is consistent with the assumption that this was by diffusion through the intercellular spaces in the roots which they measured.

The creeping root-stock and clum of *P. distichum* have well developed intercellular space system. A section of the leaf also shows that intercellular spaces are present on either side of the large vascular bundle in the region of the keel (cf. Metcalfe 1960). This means that in *P. distichum* the intercellular spaces in the aerial parts can provide the channels for the internal diffusion of oxygen down to the roots.

In water-logged soils the roots have to experience a deficiency of oxygen. The intercellular spaces provide a path for the internal diffusion of oxygen from the shoots down to the roots with the result that the concentration of oxygen inside the roots will be higher as compared to that in the soil, thus there can be outward diffusion of oxygen from them. Recent researches have shown that there is a definite outward diffusion of oxygen from the roots of the plants growing in badly water-logged soils (Van Der Heide *et al.* 1963, Armstrong 1964, Teal and Kanwisher 1966). It can be safely assumed that, likewise, there is some inward diffusion of carbon dioxide from the soil into the roots in view of a very high concentration of carbon dioxide in the soil atmosphere (soil water and soil air) in which the roots are growing.

Iron is quite sensitive to changes in the oxidation-reduction potentials in soils (Merkle 1955). The orange brown deposits found on the roots of many other plants have been shown to be iron oxides (Bartlett 1961). The presence of such deposits on the roots of *P. distichum* from deeper soil depths indicates that the conditions for oxidation are better near the root surface and is an evidence of the outward diffusion of oxygen from the roots.

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